DIVERSITY AND STRUCTURE OF MILLIPEDE COMMUNITIES (*Diplopoda*) IN FOUR DIFFERENT BIOTOPES

KAREL TAJOVSKÝ

Institute of Soil Biology, Academy of Sciences of the Czech Republic, Na sádkách 7, 370 05 České Budějovice, The Czech Republic

Abstract

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Data from long-term observation of millipede communities in four different biotopes (field, fallow, meadow, forest), investigated as successive stages of abandoned fields, were used for evaluating their diversity and population structure. Species number as well as mean densities increased always from a field in crop rotation to older fallows, and in a forest soil (subclimax stage) these characteristics slightly decreased. The species diversity (Shannon-Wiener's index) had the same course, as well. While in field in crop rotation species of the wedge ecomorphological type (order Polydesmida) predominated, in fallow millipede community subsequently differentiated (orders Julida, Polydesmida, Chordeumatida, and Glomerida). In forest the order Glomerida was the most abundant. Presence of vegetation cover and food resources seem to be important factors acting on the distribution and diversity of millipede populations.

Introduction

Millipedes (*Diplopoda*) are important members of litter and soil fauna in most terrestrial ecosystems. As saprophagous invertebrates they consume annually quantity of dead organic matter, above all decaying plant litter. The majority of food is imperfectly digested and is excreted in a form of faecal pellets back into the soil (Gilyarov, 1970). This way millipedes stimulate soil and litter microflora and accelerate decomposition processes in soil environment (Anderson et al., 1985; Price, 1988). Consequently in temperate regions millipedes are abundant in biotopes with sufficient food resources, above all in forests and grassland soils. In man influenced and/or disturbed biotopes including arable lands millipede populations decrease and are very low or missing. Nevertheless they belong to the invertebrates which are able to recolonize new biotopes including suburban fallow areas, reclaimed lands etc. (Strueve-Kusenberg, 1982; Dunger, Voigtländer, 1990).

The results of a 6 year investigation of millipede succession in abandoned fields (Project of the Institute of Soil Biology, České Budějovice) were used for the demonstration of diversity and structure of millipede communitie changes in four different successional stages of an entric cambisol.

Material and methods

The millipede communities were investigated during the years 1986–1991 in four plots denominated as (1) field, (2) fallow, (3) meadow and (4) forest belonging to a secondary successional row. All these plots are situated in South Bohemia near Chelčice (field, fallow, meadow, 49°06' N, 14°07' E, 560 m a.s.l.) and Malovice-Hradiště villages (forest, 49°04' N, 14°09' E, 480 m a.s.l.). Field is the initial stage of succession with the crop rotation (1986 wheat, 1987 potatoes, 1988 barley, 1989 mixture of oats, peat and clover, 1990 clover, 1991 without any product). Fallow is an abandoned field, since the autumn 1985 without any crop rotation and with a significant successive development of vegetation from 1986 (plant association *Apera spica-venti*, alliance *Aphanion*). Meadow is a field abandoned in 1975–1977, then regularly mown up to 1986 with a plant community *Agropyron repens - Holcus mollis* (alliance *Arrhenaterion*), in the years 1986–1991 as a 10 to 15 year old fallow. Forest as a subclimax of this region is represented by a 60–70 year old mixed acidophilous oak wood (plant community *Abieto-Quercetum*, alliance *Genisto germaniacae-Quercion*). The examined area is characterized by a brown soil type (entric cambisol), field and fallow with plough horizon, meadow with mull humus horizon, and forest with mull-moder humus horizon. Yearly mean air temperature is 7.3 °C, precipitation per year 650 mm.

Soil samples (5 from each plot, area 1/16 m^2, depth 10 cm) were taken from all four plots in 3 month intervals from May 1986 and extracted with a modified Kempson extraction apparatus (Kempson et al., 1963). The obtained millipedes were determined and mean densities (number of individuals per m^2) and Shannon-Wiener's index (H'_{log2}) of species diversity (Odum, 1971) were calculated and used for the evaluation of millipede communities diversity on separate biotopes. For further possible diversity characterization relative densities of the millipede ecomorphological types were used (Eisenbeis, Wichard, 1987; Hopkin, Read, 1992) as follows: (1) bulldozers or rammers – burrowing in earth (in temperate regions with representatives of the order Julida), (2) wedge types – with morphological and ecological adaptations to burrowing and lifestyle among decaying leaves (order Polydesmida), (3) borers – with specific boring type of locomotion (orders Chordeumatida and Colobognatha), (4) rollers – able to bulldoze and also roll into a sphere (order Glomerida) and (5) bark dwellers – order Polyxenida without any burrowing capability and leaving under a peeling bark.

Results and discussion

The total species composition in the four biotopes obtained during the 6 year investigation is given in Table 1. The highest number of millipede species was noted in the meadow. The number of species established in a field can be at variance with the fact, that millipedes are not abundant in arable lands. With changing conditions (crop rotation) during the years the poor species spectrum varied, and minimum cultivation in the last two years made the penetration of further species possible. This situation is more perceptible in Table 2, where the numbers of species and mean densities are given for investigated biotopes and years separately. These data allow us to consider successive changes among individual four biotopes as well as the changes within the frame-

work of each biotope during the 6 year observation. Almost every year number of species and their density increased from the field to fallow and meadow where they culminated, whereas in the forest they slightly decreased again. Fallow, developing from 1986 as an abandoned field, was characterized by an outstanding increase in the

Table 1. List of millipede species in the field (1), fallow (2), meadow (3) and forest (4)

	(1)	(2)	(3)	(4)
Order Glomerida				
Glomeris hexasticha Brandt, 1833	+	+	+	+
Order Julida				
Blaniulinae sp. (juveniles)	–	+	–	+
Julus scandinavius Latzel, 1884	+	+	+	+
Leptoiulus marcomannius Verhoeff, 1913	–	+	+	+
Unciger foetidus (C.L. Koch, 1838)	+	+	+	+
Unciger transsilvanicus (Verhoeff, 1899)	–	–	+	–
Megaphyllum projectum (Verhoeff, 1907)	+	+	+	+
Megaphyllum unilineatum (C. L. Koch, 1838)	–	–	+	–
Ommatoiulus sabulosus (Linnaeus, 1758)	+	+	+	–
Order Chordeumatida				
Mastigona mutabilis (Latzel, 1884)	+	+	+	+
Haasea germanica (Verhoeff, 1901)	+	+	+	–
Ochogona caroli (Rothenbuehler, 1900)	+	+	+	+
Order Polydesmida				
Polydesmus complanatus (Linnaeus, 1761)	+	+	+	+
Polydesmus denticulatus C.L. Koch, 1874	+	+	+	–
Total	10	12	13	9

number of species (the second year) and density (up to the third year), as well. Nevertheless, in the meadow and forest the populations of millipedes did not stay stable and changed during the years, too.

The values of species diversity showed in subsequent successive stages the same course as the number of species and their density did (Table 3). The fluctuation of

Table 2. Number of species/mean annual densities (ind.m^{-2}) of millipede communities in separate plots

	1986	1987	1988	1989	1990	1991
Field	2/1.4	3/4.8	2/10.4	2/30.4	6/68.8	5/20.8
Fallow	2/3.2	8/14.4	8/128.8	9/117.6	8/140.0	9/41.0
Meadow	9/59.1	9/72.0	10/105.6	13/182.4	13/142.4	11/198.4
Forest	4/52.2	4/26.4	8/36.0	8/85.6	8/116.8	9/40.0

density values for field, their increase in the second year for the fallow, and the highest values for the meadow were established.

Numerous estimates of the densities and population structure of millipedes have been published in a wide range of habitats (cf. Hopkin, Read, 1992). Our results of the highest density and diversity in a meadow grassland confirmed that such localities could be also a suitable environment for these saprophagous invertebrates. Man influences supressed millipede communities through agricultural activities in arable lands. An interruption of cultivation in the fallow under study and/or mere discontinuance of mowing on the meadow led to the development of those communities. It confirms the fact that vegetation cover as a source of shelters, microclimatic changes and dead plant

Table 3. Diversity (bits) of millipede communities in separate plots

	1986	1987	1988	1989	1990	1991
Field	0.940	1.459	1.239	0.398	1.375	1.773
Fallow	0.928	2.600	2.847	2.770	2.829	1.773
Meadow	2.811	2.752	3.212	3.069	3.083	2.981
Forest	1.412	1.531	2.268	2.206	2.317	2.510

material, and food resources themselves may belong to the factors acting on the distribution and diversification of millipede populations.

There are several approaches to classify millipedes into biological-ecological or ecomorphological life forms or types (Golovatch, 1987; Eisenbeis, Wichard, 1987; Hopkin, Read, 1992). Using such classifications can contribute to the evaluation of diversity respecting many other characters of those invertebrates. Ecomorphological types according to Hopkin, Read (1992) proceed from the Eisenbeis' and Wichard's (1987) five forms and can be viewed in the light of Manton's interpretation of functional morphology (Manton, 1977). Representatives of the four ecomorphological types were presented in the plots under study. Their relative densities (in %) are given in Table 4. For the explanation of the share and changes of separate ecomorphological types it is

Table 4. Relative densities (%) of four ecomorphological types of millipedes. Jul – bulldozers, Julida; Pol – wedge types, Polydesmida; Cho – borers, Chordeumatida; Glo – rollers, Glomerida

		1986	1987	1988	1989	1990	1991
Field	Jul	33.3	33.3	7.8	7.9	24.5	57.7
	Pol	66.7	66.7	92.2	92.1	70.9	30.8
	Cho	–	–	–	–	4.6	3.8
	Glo	–	–	–	–	–	7.7
Fallow	Jul	100.0	83.2	68.4	65.3	58.9	25.4
	Pol	–	5.6	19.8	12.3	16.0	12.9
	Cho	–	5.6	6.2	5.4	12.0	8.6
	Glo	–	5.6	5.6	17.0	13.1	53.1
Meadow	Jul	69.4	75.6	51.5	53.5	35.7	43.9
	Pol	9.0	5.6	23.5	16.7	11.2	3.6
	Cho	1.8	–	3.8	6.6	32.0	25.5
	Glo	19.8	18.8	21.2	23.2	21.1	27.0
Forest	Jul	36.8	39.4	28.8	14.0	18.5	38.0
	Pol	4.0	3.0	22.2	21.5	23.9	6.0
	Cho	–	–	2.2	15.9	31.6	10.0
	Glo	59.2	57.6	46.8	48.6	26.0	46.0

necessary to consider further parameters of those invertebrates, such as life-history, postembryonal development etc. For example the type bulldozers – Julida were present in all localities. A high portion in fallow is connected probably with their high mobility. Their percentual share decreased with the diversification of life conditions in this biotope and differentiation of millipede community. The life cycle of the present species – bulldozers is more than two years (David, 1992), therefore they were not able to resist or to develop permanently in the field in crop rotation. The found species were really mostly adults penetrating there for a short time from surrounding biotopes. A substantial part of the community in the field formed the wedge types – Polydesmida, although they are often inhabitants of litter layers, more intensely aggregated, but also much more active than some others (Blower, 1969). Probably they are rather more r-strategists than the rest of the millipede colonizers. Rollers – Glomerida, disregarding their ecomorphological adaptations to water loss, were collected in the field only

in 1991 when this plot became more or less abandoned. In the fallow their share did not increase before vegetation development. According to data from the forest the representative of rollers, *Glomeris hexasticha*, could be designated as species mainly inhabiting forest soils.

Conclusion

The diversity of millipede communities increased from the field in crop rotation to a fallow and culminated in the meadow, otherwise it increased in the course of the secondary succession. In subclimax forest stage the diversity slightly decreased. These results confirmed not only the values of diversity, but also the numbers of species and their mean densities.

For the diversity estimation of such animals as millipedes, further characteristics as ecomorphological life/forms are useful. Nevertheless some other ecobiological characteristics were necessary to explain the used ecomorphological types.

Translated by the author

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Tajovský K.: **Diverzita a struktura společenstev mnohonožek *(Diplopoda)* na čtyřech různých biotopech.**

Údaje z dlouhodobého sledování společenstev mnohonožek na čtyřech rozdílných biotopech (pole, úhor, louka, les), zkoumaných jako sukcesní stadia opuštěných polí, byly použity pro posouzení diverzity a struktury populací těchto půdních bezobratlých. Počty druhů a průměrné abundance narůstaly vždy od obdělávaného pole ke starším úhorovým stadiím. V lesním subklimaxovém stupni hodnoty těchto charakteristik mírně klesaly. Hodnoty Shannon-Wienerova indexu druhové diverzity se rovněž zvyšovaly až po louku a v lese byly nižší. Zatímco na obdělávaném poli dominovali zástupci tzv. klínovitého ekomorfologického typu (wedge type), tj. zástupci řádu Polydesmida, na úhoru se společenstvo mnohonožek postupně diferencovalo (řády Julida, Polydesmida, Chordeumatida, Glomerida). V lese byly nejvíce zastoupeny mnohonožky řádu Glomerida. Přítomnost a rozvoj rostlinného krytu a potravní zdroje ovlivňovaly šíření a rozmanitost populací mnohonožek.